National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean Resources Conservation and Assessment
Strategic Environmental Assessments Division's

# BIOGEOGRAPHY PROGRAM: Coupling Species Distributions and Habitat

## Introduction

This paper summarizes the activities of the Office of Ocean Resources Conservation and Assessment Strategic Environmental Assessment (SEA) Division to define and interpret the coupling of species distributions and their habitat requirements in estuarine and coastal environments. The work of the Division's Biogeographic Characterization Branch has been formulated to support the development of assessment tools that support habitat and living resources management. The goal of the Biogeography Program is to develop knowledge of living marine resource distributions and ecology throughout the Nation's marine, coastal, and estuarine environments to provide managers with an improved ecosystem basis for making decisions.

SEA's species/habitat coupling work is addressed through a continuum of approaches to define bio-physical relationships which differ in data content, complexity, and analytical structure (Figure 1). Examples of four approaches are presented below.

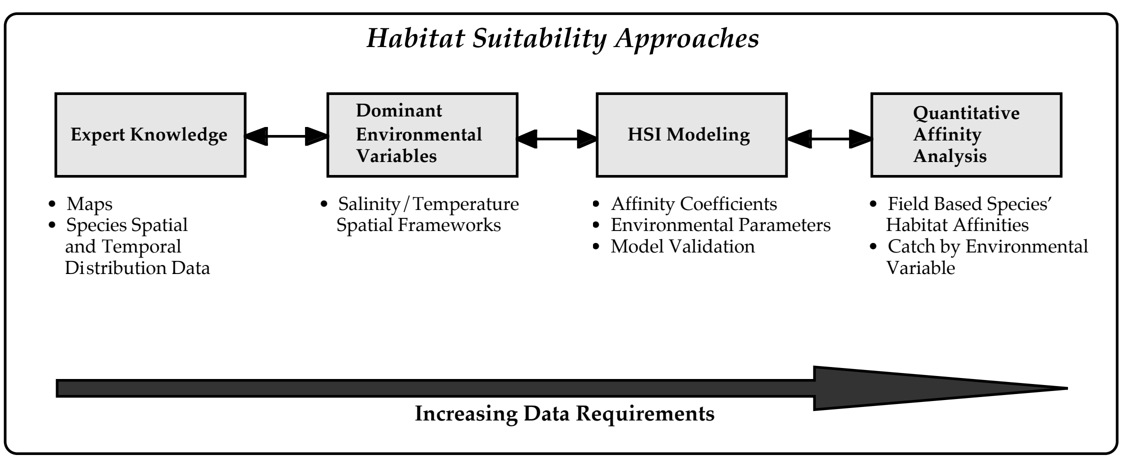


*Figure 1. Four approaches to coupling species distribution and habitat.*

Monaco, M.E., and J.D. Christensen. 1997. Coupling Species Distributions and Habitat. *In:* Changing Oceans and Changing Fisheries: Environmental Data for Fisheries Research and Management (G.W. Boehlert and J.D. Schumacher, eds.) NMFS Technical Memorandum

## 1) Expert Review

This approach uses and builds on SEA's development of a series of strategic assessment coastal atlases along the nation's coastlines (Figure 2) (NOAA 1986; Strategic Assessment Branch, 1989). An important theme in the atlas series is the distribution, relative abundance, and life history function of living marine resources. Species distribution maps are synthesized from a multitude of quantitative and qualitative data sources. The integrated data and maps are peer reviewed by recognized experts on specific species and geographic areas. Where data are available, species are mapped and associated environmental variables are analyzed to interpret species distributions (Brown *et al*. 1996). In areas where data are not available, species distributions are inferred based on knowledge of a species' habitat requirements and the geographic extent of those habitats. This sort of information is developed in expert review meetings and workshops where structured approaches are used to "engineer" our collective knowledge.

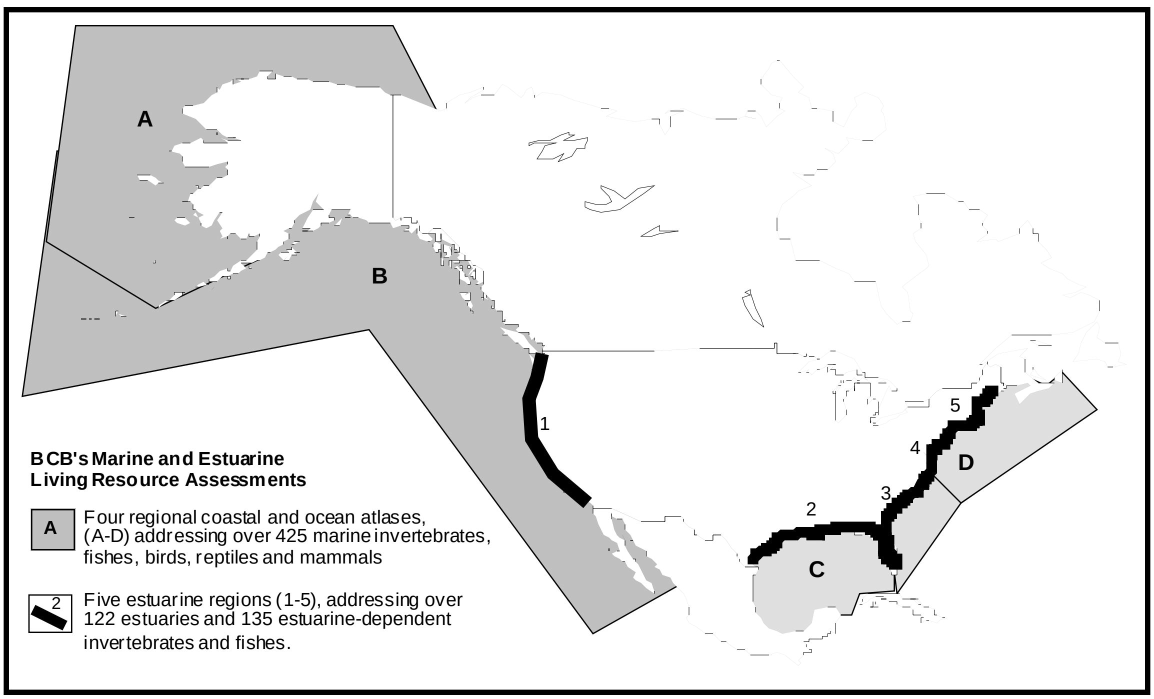


*Figure 2. Geographic coverage of SEA's Biogeography Program.*

## 2) Controlling Environmental Variables

Estuarine salinity (3-5 zones per estuary) and temperature (monthly) variables provide the spatial and temporal framework to organize species distribution and relative abundance data. The primary data developed for each species include spatial distribution by salinity zone, temporal distribution by month, and relative abundance by life stage (e.g., adult, spawning, juvenile, larva, and egg). These data, along with a series of species life history tables that characterize species habitat requirements, are the major components of SEA's Estuarine Living Marine Resources (ELMR) Program (Jury *et al*. 1994). Over 6,000 species/estuary data sheet combinations have been compiled and peer reviewed for 135 species in 122 continental U.S. estuaries.

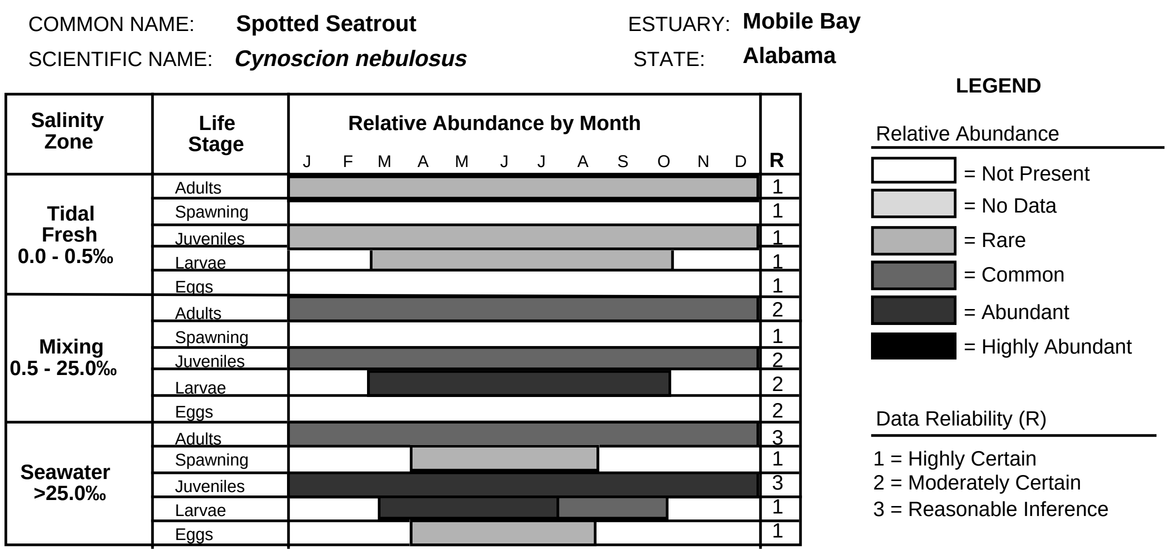


*Figure 3. Example ELMR data sheet.*

## 3) Habitat Suitability Index (HSI) Modeling

SEA is developing a series of species habitat suitability index (HSI) models to support species/habitat management (Figure 4). The methodologies were

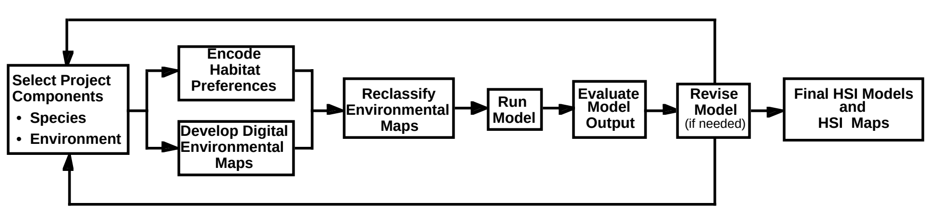


*Figure 4. The process of developing and running an HSI model.*

developed by the U.S. Fish and Wildlife Service (Soniat and Brody 1988); SEA refined the suitability index coefficients and employed geographic information system (GIS) technology for map development. The HSI concept centers around the assumption that the "value" or "importance" of a geographic area can be defined by estimating a species' habitat requirements and quantifying habitat availability. A species' habitat affinity (preference) for specific environmental variables (e.g., salinity zones) is encoded to a suitability index (SI) scale ranging from zero (for unsuitable habitat) to one (optimum habitat). SI values are assigned based on the literature or quantitative analyses (see below) to define the strength of species habitat affinities (Monaco *et al.* in review). Digital maps of environmental parameters are developed via GIS technology. A simple model is used to calculate a geometric mean suitability for a specific grid cell (e.g., 100 m X 100 m):

$$HSI = \left[\prod_{i=1}^{n}(SI_i)\right]^{(1/n)}$$

where the $SI_i$ are the suitability indices for environmental variables 1 through n (Figure 5). Model outputs range between zero and one; any grid cell having one or more environmental characteristics in the unsuitable range will have an HSI of zero.

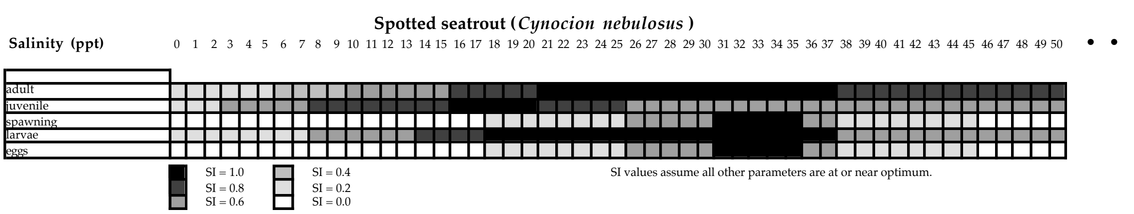

*Figure 5. Salinity suitability index coefficients for spotted seatrout.*

**4) Quantitative Habitat Affinity Indices (HAI)**

Quantitative analysis to define species habitat affinities depend on having field-based databases that provide species catch rate and simultaneous measurements of habitat/environmental variables. For example, we have analyzed databases on the occurrence of fish and invertebrate species by salinity increment (Figure 6) to determine how species organize themselves across salinity space in East Coast and Gulf of Mexico estuaries (Lowery *et al.* in prep, Bulger *et al*. 1993). In these studies, principal component analysis identified five biologically based salinity zones across the estuarine salinity gradient.

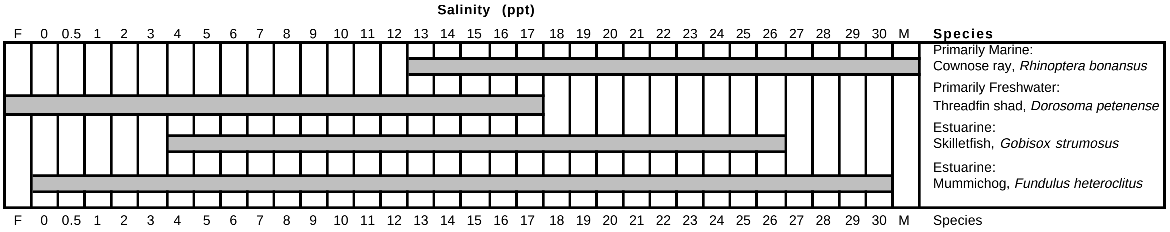


*Figure 6. Example of species-salinity data matrix (Bulger et al. 1983).*

We also analyzed time-series data sets that contained species catch by their habitat variables to measure the repeatability of a species' response to environmental parameters (Monaco *et al.* in review). We quantified species habitat affinities based on the relative concentration of a species in a specific habitat (e.g., depth zone) when compared to the relative availability of that habitat throughout the study area. To quantify species habitat affinities, we developed a habitat affinity index (HAI) based on a modification of the Strauss (1979) electivity index:

$$\mathrm{HAI} = (p - r)/\ r, \ \text{if } p < r$$

*or*

$$\mathrm{HAI} = (p - r)/(1 - r), \ \text{if } p > r$$

where p is the proportion of species collected in a specific habitat and r is the proportion of area that habitat comprises in the study area. The HAI has a center point of zero; therefore, the index is scaled so that an HAI of -1 corresponds to non-collection or complete avoidance of an area (Table 1). An HAI of 0 indicates that fish displayed no habitat affinity, and an HAI of +1 indicates an apparent exclusive affinity for a specific habitat zone or area. Negative values (other than -1) are used to define avoidance, and are not equivalent to complete absence; a negative HAI value in the electivity context reflects a lesser concentration of a species in a particular habitat.

*Table 1 . Species Habitat Affinity Index values for environmental and geographic variables in the mid-Atlantic region. Shaded values indicate a statistically significant affinity (+) or avoidance (-) (Monaco et al. in review).*

| | | SALINITY ZONES (ppt) | | | | | SUBSTRATE (% SILT/CLAY) | | |
|---|---|---|---|---|---|---|---|---|---|
| SPECIES Life stage | | 0 - 0.5 | 0.5 - <5 | 5 - < 15 | 15 - < 25 | > 25 | 0 < 20 | 20 - ≤ 80 | > 80 |
| SPOT | AVG HPI | -0.939 | 0.012 | 0.164 | 0.380 | -0.816 | -0.577 | -0.057 | 0.304 |
| Juvenile | STD ERROR | 0.047 | 0.006 | 0.091 | 0.103 | 0.059 | 0.144 | 0.103 | 0.191 |
| WEAKFISH | AVG HPI | -1.000 | -1.000 | -0.792 | 0.646 | -0.542 | -0.618 | 0.220 | -0.242 |
| Adult | STD ERROR | 0.000 | 0.000 | 0.202 | 0.202 | 0.325 | 0.180 | 0.371 | 0.377 |
| HOGCHOKER | AVG HPI | -0.014 | 0.244 | 0.119 | -0.668 | -0.898 | -0.719 | -0.546 | 0.649 |
| Juvenile | STD ERROR | 0.065 | 0.280 | 0.406 | 0.083 | 0.102 | 0.133 | 0.211 | 0.127 |

## Current Applications

SEA's mix of approaches to define bio-physical relationships is currently supporting several joint studies and clients. For example, data from the ELMR Program supports mapping products for the National Marine Fisheries Service Office of Habitat Protection by helping define essential fish habitat (Schreiber and Gill 1995), and for the Atlantic States Marine Fisheries Commission's weakfish management plan (Lockhart *et al.* 1996). In addition, ELMR program data are currently being integrated into the next generation of Environmental Sensitivity Index maps under a joint program of NOAA, the Minerals Management Service, and states in the Southeast and Gulf of Mexico regions (Battista *et al.* 1996).

Habitat Suitability Index models for white shrimp, eastern oyster, and spotted seatrout in Pensacola Bay, FL are under development to support the EPA's Gulf of Mexico Freshwater Inflow Committee efforts to assess impacts of changing estuarine salinity regimes (Christensen *et al.* in press). This pilot study provides an analytical approach to conduct similar investigations across the Gulf of Mexico region. In addition, HSI models have been developed in Maine for Casco and Sheepscott Bays to support the Gulf of Maine Program. This work identifies important areas for management in the Gulf.

Quantitative analysis to define species habitat affinities are underway using the EPA/NOAA Environmental Monitoring and Assessment Program (EMAP) Carolinian Province database. SEA's Habitat Affinity Index will be used to assess whether differences in species' response to their environment can be detected in polluted versus non-polluted areas in the south Atlantic region.

## Concluding Comments

Defining quantitative habitat affinities provides new opportunities for aquatic resource management. The identification and protection of species habitat are increasingly recognized as complements to traditional harvest management approaches, and as critical parts of maintaining living resources (Deegan and Day 1984; Funderburke *et al.* 1991; Chambers 1992). A prerequisite for implementing habitat management approaches is an understanding of species habitat requirements. SEA's Biogeography Program will continue to develop and provide information to define the coupling of species to their habitats on national, regional, and local spatial scales.

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